

# THE PROCEEDINGS *of* THE INSTITUTION OF PRODUCTION ENGINEERS

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Members are requested to correspond with the Editor upon matters of general interest. Letters may take the form of descriptions of unusual plant or tools, workshop methods, production problems or organisation systems. Only in exceptional circumstances will proprietary articles be dealt with editorially. Manufacturers wishing to draw the attention of the Institution to the merits of their products are invited to use the advertisement columns of this Journal. All correspondence should be addressed to the General Secretary, Institution of Production Engineers, 40, Great James Street, Bedford Row, London, W.C.1.

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## GAUGING AND MEASURING METHODS

Paper presented to the Institution, Luton, Bedford and District Section, 8th January, 1930, by W. H. Carter (Member).

(Also presented to Manchester Section, 14th April, 1930).

A BIOGRAPHER examines the ancestry of a man whose life he records in order to trace the development of peculiar traits and talents. Similarly, in order to understand the technique of a craft or science its ancestry must be investigated. In apologising for the opening nature of my paper, I trust that you will agree with me when I say that in reviewing the subject or science of measurement it is our duty first of all to refer, however briefly, to the initial phases through which it has passed, and by so doing pay homage which is due to the genius of the great masters who laid the foundation upon which it has been built.

Considering firstly the metrical systems of the ancients, we find that these were both of the sexagesimal and centesimal character. The writings of Greek philosophers shew that the sexagesimal system was derived from the division of the Zodiac by the Chal-

deans, a people who dwelt in Mesopotamia about 2,000 B.C., and who were masters of astrology and astronomy, and were, without doubt, proficient in mathematics and methods of measurements. The origin of the calendar is attributed to them, the ancient year consisting of 360 days, the sun or earth in each day describing the 360th part of the orbit. Theon in his work mentions a work of the philosopher Hipparchus, about a century and a half B.C., in which he used sexagesimal arithmetic throughout, and explained the method of dividing the circle into 360 parts, the radius being equal to the chord of sixty of those parts. (Hexagon—the radius has been decimaly divided, but the sexagesimal divisions of the arc have continued to be expressed and used to the present day, although there has been several attempts at reformation of the system to that of the centesimal, but without results).

Regarding the origin of the centesimal system, it is conjectured that the earliest aids to calculation were the human fingers, and that from them *ten* became what may be termed the dominant number. This primitive methods appears in the *Roman system*, from the seven letters of which all the numerals are formed. I, V, X, L, C, D, M. Beginning with a series of strokes I, II, III representing the fingers, the shape of the fore-finger and thumb, extended V, indicated 5. Two V's joined thus gave the symbol X, indicating 10. Additions to these numbers were made by placing strokes on the right-hand side, e.g., VIII for 8, deductions from them by strokes on the left-hand side, thus IX for 9. One hundred is indicated by the initial letter of the Latin word "centum" meaning a hundred, this being originally written █. Half of this letter was used to signify fifty, gradually coming to be written as the letter L. In the same manner D (500) is half of the old Roman M, the initial letter of the word "mille" meaning a thousand.

With regard to the Arabic system, two theories exist as to the origin of the recognised symbols—that they were evolved out of an arrangement of strokes, or that the form of the figures were invented from a divided square, the figures on mediæval inscriptions bearing evidence how they can be traced.

We therefore find that the ancients utilised natural resources in the way of establishing a basic for their numeral system, and from those very earliest times the trend was also to utilise and establish what may be termed a natural standard for length measurement, thus the unit adopted formed some part of the human body. For instance, the hand or palm equal to four inches approximately, this measure surviving to the present day being expressed in the measurement of cattle, the foot presumed to be of Grecian origin and derived from the foot of Hercules, and the stride a human measure used by the Babylonians, who employed men of uniform

stature termed Bematists or step measurers, for the survey of conquered lands.

The cubit, which figured as a national standard for both the Egyptian and Hebrew races, differed in length, the Egyptian cubit as used in the construction of the pyramids, 14th to 18th Dynasty (about 1,500 B.C.) being about seventeen and three-quarter inches, whilst the Hebrew equalled about twenty-one and a half inches. This standard undoubtedly had for its origin part of the human body, for we find that proof is established by the Latin word "cubitum" meaning elbow or bend of the arm, and the measure of length from the tip of the forefinger to the elbow.

Among the various ancient measures was one termed the ell. This measure varied in length in different countries, at different periods, and was used chiefly for measuring cloth. In England it varied from thirty inches to forty-five inches. The ell, or ulna, which is the Latin word for ell or arm, was, prior to the Norman conquest thirty-nine and a half inches, but in the year A.D. 1101 it was decreed by Henry I that the ancient ell should be the length standard, and would be equal to the length of his own arm (forty-five inches).

In the year 1197 King Richard I commanded that there should be only one standard weight and measure throughout the kingdom, the barley corn to serve for both.

One of the Anglo-Saxon measures which existed at the time of the Roman occupation was the rod, rood or pole, which was sixteen and a half feet in length. The Anglo-Saxon word meaning rod is "G Y R D" and it appears that from this word yard was evolved, also that our word inch was evolved from the Anglo-Saxon word "Y N C E" and this word derived from the Latin word "U N C I A" which means a twelfth part of, or probably it was derived from the Latin word "I N C H O O" which means "to begin" or "to erect."

This latter theory is supported to a certain extent by the statute enacted in A.D. 1324 when, during the reign of Edward II, it was decreed "that the inch shall be the length of three barley corns, round and dry, laid end to end, twelve inches shall make one foot and three feet one yard or ell, and five and a half ells one rod or perch."

Very little is known of the length standards after this date (1324) until 1742, when existing standards were exchanged by agreement between the Royal Society and the Royal Academy of Science of France.

Two bars each forty-two inches long with the lengths of three feet marked on them were sent to Paris, one of these bars being returned later with the word "toise" marked on it. The word "toise" meaning measure, rule, stretch or survey, was used in France long before the official introduction of the metre. It re-

ferred to a certain length which, according to P. B. Burnet's French Dictionary was originally six feet long (six Paris feet 1.949 m. or about 6.4 feet) whilst Toussaint's Dictionary emphasises the fact that the word "toise" was used during certain periods as a warrant on measuring appliances or rules. French history also points out that other measures were in existence about this period, so that if "la toise" was the official measure it was evidently not generally used.

In 1742 the Royal Society, after measuring the Degree of Latitude determined the length of a pendulum beating seconds, and in the year 1758 a Commission was appointed by Parliament to investigate and compare the existing standards with those furnished by the Royal Society. The Royal Society standard was copied, laid before the House of Commons, and a scale made. It was marked "Standard Yard, 1758." Two years after this date a yard bar was prepared by the scientist Bird and was marked "Standard, 1760."

About this period scientists concluded that a standard having for its basis quantities that might vary was not practical and accordingly directed their efforts to the formation of a natural basis from which a standard, in the event of it being destroyed, could be recovered. In 1774 the Royal Society favoured the pendulum principle. This principle was a modification of that suggested by Professor Huygens some years earlier as being the method that would obtain an invariable basis for the standard, and consisted of a pendulum with a movable weight attached. The vibrating seconds of mean time were counted when the weight was in one position, and again when the weight was in another position, the distance between the two positions then being measured.

Whether incited by the work of the French or not, we do not know, but in the early part of the nineteenth century the English began to do more upon the establishment of a standard, and in 1816 a Commission was appointed by the Crown to examine and report upon the standard of length, and after Captain Kater had made a long series of careful observations and tests on the second pendulum method the Commission determined the length of the standard to be 39.1386 inches when reduced to sea level. Troughton, who is accredited with being a pioneer in the use of the microscope for linear measurement, made a scale to this standard for Sir George Schuckburgh.

In 1822 a Commission investigating the matter of length standard, after making three reports, recommended that the standard yard as prepared by Bird in 1760, marked "Standard Yard, 1760" be adopted as the standard for Great Britain, and in the Act of Parliament of June, 1824, it was duly declared. When the Houses of Parliament were burned in 1834 an opportunity arose to restore the standard, Sir Francis Baily being commissioned to undertake

the work which, however, he did not complete owing to his death in 1844. After the fire the scale made by Troughton for Sir George Schuckburgh, the Royal Society yard and two iron bars that had been in use in the Crown Ordnance Department still existed, and were supposed to correspond with the prototype which had been damaged. A scientist, the Reverend R. Sheepshanks, compared a standard of his own construction with these four standards, this standard being legalised in 1855.

The Sheepshanks yard bar is known as the "Imperial Standard Yard or Bronze No. I." It consists of a bronze bar  $38'' \times 1'' \times 1''$ , the material being in accordance with Sir Francis Baily's specification, viz., sixteen parts copper, two and a half parts tin, and one part zinc.

At one inch from each end of this bar is bored a hole half an inch deep by half an inch diameter, and into the remaining depth, and concentric with the holes is fitted a gold plug one-tenth of an inch diameter, so that the surface of each plug is in the central plane of the bar, this being done in order to minimise risk of damage and also to reduce as far as possible the effects on the standard length should any flexure occur. Upon each of the polished surfaces of the gold plugs is traced two longitudinal lines and three transverse lines, the yard being defined as the distance between the centre transverse line between the longitudinal lines on the one plug to the corresponding line on the other plug. It can be said that the trade of the Empire is carried on in terms of this standard, and it is hardly necessary to say that extreme precaution is taken in its preservation.

Obviously, no system could be maintained with accuracy by the preservation of primary standards alone. There must be secondary standards in sufficient number to afford reliable comparative data as to the permanence of the primary standard, therefore copies were made, known as "Parliamentary Copies," from which the standard may legally be reconstructed if at any time lost or destroyed, these being deposited with the Royal Mint, the Royal Society, the Royal Observatory of Greenwich, the Board of Trade, and the Royal Palace of Westminster.

The copies are intercompared every ten years, and compared with the Imperial standard every twenty years. To complete the equipment of national standards, there is provided a third-class known as "Board of Trade Standards," these being compared with the Parliamentary copies once in every five years. The temperature adopted for the British standard is  $62^{\circ}$  F., and as the length of a standard bronze bar increases practically four ten-thousandths of an inch for every one degree Fahrenheit rise in temperature, extreme constancy as well as adherence to the basic temperature is observed during comparison. To obtain accuracy of .00001 it is necessary that temperature must be constant to

at least one-fortieth degree Fahrenheit. Recent investigations and experiments show that materials having a very low co-efficient of thermal expansion are more suitable for standard reference bars than bronze or platino-iridium. Two of these materials are fused silica and invar, which is an alloy of iron with thirty-six per cent. nickel, the invention of Dr. Guillaume, the Director of the Bureau de Sevres, Paris.

### The French or Metric Standard.

The length of the metre has its origin in a land survey. About the year 1790 the Royal Academy of Science of France debated as to the best method that could be used in the determination of their standard. Three proposals were put forward, namely, the pendulum beating seconds of time, the quadrant of the meridian, and the quadrant of the equator. Eventually it was decided that the standard should be based on the quadrant of the meridian, and in 1795 MM. Delambre and Mechain, two French surveyors, were entrusted with the work of measuring the arc of the meridian between Dunkirk and Barcelona and passing through Paris, an arc of approximately nine and a half degrees. As a result of their reading for this distance it was determined that the length of the metre should be approximately one ten-millionth part of the distance between the equator and the pole, and a standard bar was made accordingly by Borda.

Standard metre bars differ in material and cross section from the English standard bronzes. The material used is ninety per cent. platinum and ten per cent. iridium, having a low co-efficient of thermal expansion approximately .00036 inches per metre and degree Centigrade.

The master bar is stored at the International Bureau of Weights and Measures at Sevres, near Paris. It is a bar of Tresca  $\times$  section, the central rib carrying the lines limiting the length of the metre, the lines having a thickness of 0.008 mm. (.00032 inch) only. The nineteen States which on May 20th, 1875, in Paris, formed the International Metric Convention each received a copy of this master made in the same shape from the same metal, and small deviations being unavoidable they were determined for every single copy.

### The Length Standard of the United States of America.

Prior to 1856 the accepted standard for length in the United States of America took the form of a brass scale eighty-two inches long, prepared by Troughton for the coast survey of the States. The yard used was the thirty-six inches between the twenty-seventh and sixty-third inch of the scale. In 1856 the British Government presented to the United States a bronze bar known as "Bronze No. II." This is a copy of the English Imperial standard yard or Bronze No. I, and is the accepted English standard, being

correct in length at the temperature of  $61.79^{\circ}$  F. At the same time a bar in Low Moor iron (No. 57) was presented, this being correct in length at  $62.58^{\circ}$  F. The expansion of these bars for each degree Fahrenheit is .000342 inch and .000221 inch respectively. Although the yard is the commonly accepted standard in the United States it is not the legal standard for, in 1866, Congress passed a law making legal the metre, this being the first and only measure of length legalised by the Government. A copy of the metre taken from the original platinum bar at Paris was by formal order in 1893 denominated the "Fundamental Standard."

With reference to temperature for measurement it is considered practical nowadays to quote and work to converted figures taken on measuring instruments giving readings in either inch or metric units. Advantage is taken of the fact that one inch equals 25.4 mm. exact to within one part in a million—a lucky chance—but dependent upon the understanding that the inch and metric measures are adjusted to be correct at the same temperature, which is a matter of convention, and still the subject of controversy, the orthodox metric school holding that even customary metric measures, as distinct from the scientific standards on which they are based, should be correct at  $0^{\circ}$  C., and not at the ordinary temperature of use. This line of thought does not, however, correspond with the reasonable requirements of everyday practice since it has the effect that metre lengths of various materials having different co-efficients of expansion are no longer equal when brought to ordinary conditions, and in this country, for industrial purposes it is now the general practice to make metric and British measures both correct at the average temperature of  $62^{\circ}$  F.

#### Latest Government Report on the Ratio of the Yard to the Metre.

The ratio of the British and metric units were very carefully ascertained by co-operation between the Standards Department of the Board of Trade and the International Bureau of Weights and Measures (France) in 1883 and 1895, and the resulting value of 39.370113 inches was given legal sanction by Order in Council of May, 1898, for use as conversion factors for purposes of trade. This Order does not, however, purport to define the units of either system in terms of those of the other system, and the fundamental units for scientific purposes are still defined solely by reference to the respective prototype standards. A recent redetermination of the ratio of the yard to the metre, carried out by the National Physical Laboratory in co-operation with the Standards Department of the Board of Trade and the International Bureau of Weights and Measures (France) has led to the ratio—

$$\text{One metre} = 39.370147 \text{ inches}$$

which is regarded as probably more accurate than the legal figure

of 39.370113 inches but does not in fact differ from it by more than the possible combined errors of all the observations involved in the two determinations. From this result it follows that—

One inch = 25.399956 millimetres

or, within two parts in a million 25.4 millimetres.

### Fundamental Standards in Manufacturing.

The development of the system of standardisation and interchangeable manufacture brought up the problem of the transference of measurement from the fundamental standards to working standards so as to provide a means whereby gauges and measuring appliances that had been made by different manufacturers could be compared and verified. This problem had to be overcome by the production of lengths standards which were equal sub-divisions of an end measure yard, the measure of which had been transferred from the line standard. End measure reference standards now hold an important place where precision work is concerned, and it has now become almost general practice to consider the block gauge as first introduced into technical practice by Johansson and as now supplied by many other tool-making establishments to be the reference standard of length in manufacturing.

Undoubtedly, these gauges in their initial condition from the makers are remarkably accurate both as regards their individual sizes and also in combination, and if used solely for reference purposes and under proper temperatural conditions a very definite standard and adherence to the fundamental is maintained.

It is often observed, however, that owing to the many applications and usefulness of this type of gauge that in some establishments even the so-called reference gauges are subjected to practically continuous use on work, which renders liability, due to wear, of departure from the fundamental. A systematic checking and reading is therefore essential on some form of measuring machine or comparator, as is likewise the case with all types of working and inspection gauges.

A number of machines are available on the market which enable the difference between two similar end measures to be determined, among the best known being the original Whitworth, the Pratt and Whitney, and the Newall. All these consist of a bed on which heads fitted with measuring anvils are mounted, the one movable anvil being controlled by a micrometer screw, and the other acting as a spring controlled plunger which operates an indicator for ascertaining exactly when the conditions of contact are repeated.

Probably the principal reason why optical measuring and inspecting instruments have not previously been far more widely adopted in industry is because of the lack of suitable optical instruments for the workshop, the only microscopes and magnifiers available

being designed primarily for use in the laboratory and not for the workshop.

It is now being gradually acknowledged that although maintaining an efficient check on the tool maker by the use of first-class view-room and laboratory equipment, that it is not policy to deprive him of such appliances that have been specially designed to give assistance in tool manufacture and which undoubtedly make for efficiency.

For ascertaining small differences of length to a great degree of accuracy, the application of mechanical movements carrying springs, etc., must be reduced to a minimum. The principal employed in the Zeiss optimeter is based on the Poggendorf mirror and scale reading method. The scale lies in the principal focal plane of the telescope, and the rays proceeding from it are rendered parallel by the objective and are reflected back by a mirror so as to superimpose an image of the scale upon the latter itself in the principal focal plane. The displacement of the mirror is effected by point contact on the underside, the ball embedded in the spindle carrying the agate feeler, being the central point. The graduation in the field of view reads directly displacements of .001 mm. in the metric tube and .00005 inch in the English tube, each division being capable of sub-division by estimation.

An interesting application of optical principles is embodied in the Zeiss measuring machine, a micrometer screw not being used. One of the axioms laid down by Professor Abbé for ensuring accuracy in a measuring machine states that the axes of the anvils and the work and the measuring line of the scale should be in one line. As ordinarily applied the satisfaction of this rule involves a somewhat long and cumbersome machine even for work of moderate length. In the Zeiss machine Abbé's axiom is adhered to, the optical system being such that the scale over which the tailstock traverses is thrown through a series of prisms and collimating lenses to a setting microscope. One advantage of this method is that any errors or wave which may exist in the bed does not approximately effect the accuracy of measurement. These machines are made to measure up to twenty feet in length.

The invention of the interferometer by Professor A. A. Michelson some thirty years ago, introduced a revolutionary change into high precision measuring. By this invention it has become possible to measure with the unprecedented accuracy of fractional millionths of an inch, and to make such measurements independently of any man-made standard, by direct comparison with wave-lengths of light.

(Interferometry is based upon the light interference phenomena arising when two true plane surfaces, of which the upper one is transparent, are placed parallel or nearly parallel to and above each other, and illuminated in monochromatic light).

It is somewhat difficult to say as to which country should be credited as being the pioneers of gauging practice, for both Germany and America lay claim. However, the name of the French mechanic, Jean Laurent Palmer, who invented the screw caliper or micrometer in the year 1848, should not be forgotten. It can be said that in this country we owe the introduction to Sir Joseph Whitworth, who advocated principles of exact measurement and workmanship which were observed in his own manufactory, but it is supposed that the primary purpose of the plug and ring gauges made by Whitworth was to enable close setting of calipers and not for the testing of finished work. About fifty years ago the fixed type of snap and pin gauge began to be given preference over the jaw and leg type of caliper for general shop use, then followed the introduction of the limit type or "GO" and "NOT GO" gauges. Both the fixed and adjustable types of the external limit gauge being made or set to the high and low specified dimensions of the piece, is a responsible and important factor in production to-day.

One step forward in modern gauging practice is the elimination of the personal "feel" of the operator. Where fine tolerances are concerned, an important factor is the smoothness of the surface finish of the work being gauged, and also there are essential factors in connection with the gauge itself to be considered, viz., the design and stability and uniformity of the measuring or working pressure between the setting and application. The indicating type of gauge and comparator eliminates the personal feel and also dispenses with excessive friction between the working faces of the gauge and the work, and also allows for adjustment to be effected with regard to gauging pressures for certain classes of work, which thus obviates differences in measurement that can accrue. In passing, mention may be made of the necessity of adopting or selecting suitable measuring and gauging pressures with respect to work of such a nature that readily succumbs either diametrically or axially. It is not always possible to embody in even the most modern productive equipment the necessary means for ensuring that parts being produced are within the required limits, although credit must be given to the machine tool designer, in some instances, for the provision of sizing devices integral with the machine which control the feed or operation, and also for aiding the machine operator by the fitment of a dial indicator or indicating devices.

#### Internal Limit Gauges.

Internal limit gauges are as much a necessity in manufacture and the production of interchangeable work as those for external work. The heavy wear on the ordinary cylindrical gauge, owing to the repeated trials and friction between surfaces in fitting, makes it, in the matter of maintenance of accuracy, a rather expensive item. As is well known where fine fits are specified and the highest

form of circularity required (such as internal combustion engine cylinders, ball and roller bearings and their respective housings, etc.), it is essential that different forms of test be adopted for ascertaining any deviation from roundness, which either takes the form of ovality or what is generally termed the lobe. For instance and simplicity the curve polygon or tri-lobe is referred to and it will be seen that the distance between *two parallel tangents*, as also in the case of the circle, is constant. Curve polygons having an odd number of sides are often produced on grinding and honing appliances, etc., due to torque.

An indicating plug gauge or "passimeter" made by Zeiss, is so designed correctly to record over the range of the indicator any difference plus or minus to the nominal size or setting. The contact points, of which there are three (two fixed and one movable) are spherical, thus obviating the necessity of holding the instrument exactly in alignment with the axis of the bore being tested. A feature also that has been taken into consideration in the design of this instrument is the modification or geometric progression of the scale increments from their zero, which is an essential where three-point contact is operative. The reason for this is because where two fixed points of support arranged at an approximate angle of sixty degrees or 120 degrees, and the third movable and registering deviation, if the bore being measured is greater or smaller to the nominal or zero setting, the ratio of the movable indicating point to the fixed points is such that the real difference of the diameters is not correctly recorded unless scale modification is made.

### The Screw Thread.

The subject of the measurement of screw elements and screw control generally is a never ending topic, and much has been accomplished during recent years in the matter of standardisation and the invention of controlling appliances. The origin of the screw thread dates back to 236 B.C., and is credited to Archimedes, and evidence proves that the Romans used the invention by applying it to their wine presses and city gates. It was not until the nineteenth century that the screw actually came to the fore, and that worthy, Sir Joseph Whitworth was a pioneer in its standardisation.

When considering the strength of threaded components and also interchangability, pitch, effective diameter and also general form must be dealt with. Two threaded parts meant to fit together should bear on the sides of their threads. This is possible only if the angle and the pitch of both threads are sufficiently accurate and if, moreover, the crests of the thread on the screw are prevented from coming into contact with the roots of the thread on the nut, and conversely. In fact, in practical manufacture of most threaded parts it is impossible to have the threads bear at the same time on their sides and their crests.

A very desirable condition prevails when the threads bear on their crests only, and not on their sides. The fit between the two parts may then give the impression of being sufficiently accurate, whereas actually there is no contact between the sides, which are the only effective bearing surfaces from the standpoint of ability to withstand stresses and wear.

If the angle of thread and the pitch are correct and proper crest clearance is provided, the nature of the fit between screw and nut depends wholly on the sizes of their respective pitch diameters, just as the fit between a plain hole and a shaft depends solely on their actual diameters. Therefore, the classes of fit in a screw thread system are based in principle on different limits for the pitch diameters, and the limits for the major and minor diameters vary accordingly.

#### **Angular Measurement—Division.**

For the exact manual measurement of angles the Sine bar is probably the most recent development, the bar being fitted with two plugs or pins of equal diameter and parallel to the working face and at a centre distance of generally ten inches for ease in calculation. The working face becomes the hypotenuse of a right angled triangle, and the angle determined by the measurement of the opposite side. Considering the precision obtained with regard to length measurement, modern practice demands a like accuracy in respect to angular equidistance or division. Experiments have proved that in order to obtain high precision in division that measurement must be transferred from a master circle graduated and guaranteed in its entirety. The Zeiss optical dividing head is an appliance which fulfils this demand, the principle of construction being an extremely fine graduated glass scale mounted on the spindle which carries the work. The graduations are highly magnified by means of a microscope fitted into the body of the appliance, and in the microscope an auxiliary scale is fitted which superimposes the spindle scale graduation and enables the subdivision of the degree into minutes and seconds.

#### **Standard Taper Gauges.**

It is, of course, generally known that for taper work gauges of both plug and ring type are used for controlling the angle of turned and ground pieces to fixed standards. Some coloured substance being generally used on the gauge and transferred to the work to shew its condition to the standard.

#### **Gear Measuring.**

Among the most difficult yet the most fascinating are the various problems which arise in connection with the control and measurement of gear elements such as, in the case of spur gears, pitch or angular equidistance of teeth, parallelity of teeth to axis, pitch

diameter, radial position or symmetry of tooth profiles, etc. In the manufacture of gears it is essential, in order to obtain and maintain efficient production, that measuring apparatus be used to give the necessary assistance, as it is now generally acknowledged that the initial degree of precision obtained has a distinct bearing on the general behaviour and efficiency of the gears in use.

The smooth and quiet running of any gear is primarily dependent on the accuracy with which the tooth profiles conform to the correct theoretical shape and on the uniformity of the tooth spacing. By tooth spacing is meant the distance between either the driving or the coasting profiles on two adjacent teeth. When a gear is running only one set of profiles can be driving at a time and consequently the accuracy, or otherwise, of the coasting profiles has no influence whatever. It can be said that the only correct, or the most important measurement is that from one driving profile to an adjacent driving profile. Much has been done during recent years by firms both in this country and abroad in the matter of invention and manufacture of measuring and controlling appliances for this most important factor of the engineering world.

## THE PRODUCTION ENGINEER AND HIS PROBLEMS.

**President's Address to the Birmingham Section,  
15th January, 1930, by W. G. Grocock, Section  
President.**

**W**HEN I first learned that I had been elected President I was shaken by the two most potent human emotions—pleasure and fear—pleasure at being so honoured, and fear that I should be unable to live up to the high standard set by Mr. Hannay during his term of office. The fear was aggravated by the knowledge that acceptance of the position of President carried with it the obligation of giving an address. This was the snag. The job was entirely new to me, and for some time I could not make up my mind as to what subject I could deal with that would be of sufficient interest to the members. Finally I concluded that I would talk about ourselves and our Institution, and my talk, therefore, is on the production engineer and his problems.

In all our papers we aim to get a good discussion, and that is my primary objective in this address. I hope to be somewhat provocative so that I may draw from members expressions of opinion along certain lines which I have a feeling have not been sufficiently discussed up to now. I would, therefore, claim your indulgence while I briefly refer first to the influence that engineering has had on the advance of production during the last century, and in so doing I would like to draw your attention to the evolution of the production engineer. Secondly, I want to make some attempt to show the extent to which productive methods of industry to-day have sub-divided engineering, and lastly, try to visualise the connection between the production engineer and the expansion of production which must take place in the future.

### Pioneers of the Past.

When we look back to the time of Watts, Boulton, and Stevenson, and realise that during the time that has passed since then, the standard of comfort of our people has been advanced probably more than it had in the previous thousand years, we, as production engineers, have food for thought, particularly when we find that this rapid advance has been due largely to the influence of the engineer.

If any of my audience found himself on a deserted island with a hammer and chisel, and an assortment of scrap iron, it would

not be long before he had constructed a lathe, and would follow this by making either a windmill or a water wheel as the source of power to lighten his labour. He would, no doubt, soon follow by making some crude form of truck to assist him in his transport problems. We could all of us, no doubt, do this if we were forced into such a position, but should we all remember how much we owed to those engineers who have passed? These men built the foundations for the huge edifice we now call engineering, and the more we examine the work they did, the more amazed we are at the soundness of the foundation they prepared for us. We have been told that "Mankind would make very little progress in any science or art if they made no use of the experience of their predecessors." Those early engineers soon realised this truth and formed amongst themselves associations which should act in the way of bringing them together, thus forming a clearing house for their ideas. The basic idea then, as now, was that their Institutions should arrange meetings, etc., so that searchers after truth could gather together and collect grains of knowledge, thus building up experience which would be useful to their generation and posterity.

Retrospect shows us that the rapid increase in the standard of comfort we are enjoying to-day is largely the result of the work of those pioneers. By the introduction of machinery they not only replaced the drudgery of labour by mechanical means, but these machines did more than remove drudgery—they increased production enormously. Transport, too, kept pace, and assisted in the distribution of the commodities thus made.

#### **Evolution of Production Engineers.**

During the nineteenth century, not only did the work done by the engineer grow very rapidly, but it became extremely complicated, with the result that some measure of specialisation was forced on the engineering industry. It soon became apparent, for instance, that the only way to make articles in quantity, and cheaply enough to extend our markets, was to make them accurately within certain limits, and this was the birth of interchangeability. This change in the basis of manufacture eventually made a wonderful difference, both in quantity, quality and price. Incidentally, too, it was the real beginning of the production engineer, although it was many years later before the name came into current use.

Interchangeability is impossible without standardised tools and gauges, and this development brought along eventually the tool room. At this stage the tool designer materialised, first as a junior who could put on to paper the ideas of the tool room foreman and others, later as a specialist with his own ideas. Now no one can design efficient jigs and tools or gauges without a full knowledge of the operations and processes involved, and the necessity for having the operations in a logical sequence is recognised as one of

the first considerations for successful manufacture. Here, then, was the beginning of the planning department.

The next step that we were forced to take was to have someone to see that the work, instead of stopping on the floor after the first operation, was carried forward and progressed at the desired rate from one operation to the next until finished. This brought along the progress man, and at this stage, or hereabouts, inspection was found to be necessary.

A proper co-relation between the manufacture was found to be essential if we were to get work through in the desired time, and this led us by uneasy (I almost said easy) stages to the production department. Here experience soon demonstrated that to be successful, the man in charge of production must not only control the manufacturing processes from the very beginning, but he must also control the supply of raw material, and this brought forth the production engineer, and incidentally, an Institution to serve his needs.

From this brief summary of the past it will be seen that as engineering developed it became more complicated, and very naturally, first one section then others, were forced to the conclusion that they must have some means of keeping in touch with the latest developments of their particular sphere of activity. This led, ultimately, to the founding of the Institution of Production Engineers.

### Is Our Institution Needed ?

The advisability or otherwise of this division into groups of the activities of engineers has often been questioned by the ill-informed. It has been suggested that this sub-division is not necessary, but industry is too complicated to-day for any one institution to cater fully for its various sections. They are all necessary. One might just as well question the development of machine tools we use. Starting with the primary machine tool, the lathe, we progressed step by step to the planer, the shaper, and the miller to the grinding machine, and from each of these there are many sub-divisions of type, some standard, many special. No one questions this development, as we know that all are useful in their own particular spheres. So it is with the many sub-divisions from the parent institution. There are no clear lines of demarcation between some of them, and quite often their interests overlap, but in general, each section feels that it must have a technique of its own.

Professor Huxley once said, "As industry becomes more complicated and competition more keen, the sciences are dragged in one by one to take part in the fray, and he who can best avail himself of this help is the man who will come out uppermost in the struggle for existence." Production engineers realising this truth knew that they must have a technique of their own, and to establish this the Institution was founded so that the knowledge of many

could be used to form the basis of a new and more scientific conception of what is meant by a production engineer.

Arising out of this we may reasonably ask ourselves the question : What are we doing to justify our existence as a separate Institution ? In this respect I would like to call members' attention to our syllabus of papers and discussions for the past and present session. A study of these will show that all are vital to a proper appreciation of the problems of production. It will show also that no other institution covers the same line of activities, or even approaches the subjects that we, as production engineers, wish to have discussed.

### What is a Production Engineer ?

It is opportune now, I think, to ask the questions : What is a production engineer ? What is his work ? What are his problems ? Before we can get an answer to these we have to ask ourselves, what is an engineer, and what is engineering ?

I do not propose to try and define what an engineer is. I would rather attempt to deal with what an engineer does—and that is engineering. The best definition that I know is, engineering develops and standardises, translating the scientists' work into practical appliances for human good. If we accept this, then the obvious definition for, or of, a production engineer, is that he is a trained engineer who is engaged in producing by mechanical means and otherwise, any commodity which will maintain, or improve the standard of comfort of the community. These commodities he must make from any and all the materials that nature and the scientists have placed at his disposal. His chief problem is that of devising ways and means to increase the productivity of the particular plant to which he is attached.

During the time that our friend Mr. Hannay has occupied the Presidency of this section of the Institution, he has never lost an opportunity of preaching the gospel of increased production. He has said over and over again that we should aim at doubling our production, and as soon as this has been achieved, his view is that we should set out again to double it. What Mr. Hannay meant was not that we should double our working force, and thus double our production, but that the production per unit should be increased, that is, the output per individual employee, or per square foot of manufacturing area must be increased, doubled, and trebled if possible.

There is no need for me to apologise to production men for emphasising the need for further production, the subject is one which most of us regard as not only vital to the industry we serve, but vital also to a national ideal of an improved standard of living. Since we can only consume nationally the equivalent of that which we produce, then the higher national standard of living can only be obtained by

increased productivity. Even our politicians are beginning to realise this truth.

What are the principle problems which the production engineer has to face? In my opinion, these can be roughly divided as concerning themselves with *men, machines and methods*.

### Men.

The most important of these, obviously, is the study of mankind. There is no study more interesting, neither will any of our studies yield a greater return than that of the study of mankind. As production engineers we know that even if we have the best steel the scientists have given us, it will fail to function properly unless it is also treated properly. Even the ordinary low-class steels will, when subjected to the proper treatment, yield better results than if left in their natural condition, or untreated. This is particularly true of the human material that we have to handle to achieve our ends. From the point of humanity alone it should be treated well, but from the point of view of production, proper treatment will yield ample returns for any effort we may expend in this direction.

On this question of increased production we are constantly hearing of, and having comparisons drawn between, the higher outputs obtained in America and the outputs that are obtained here. Usually it is found, when carefully examined, that these comparisons are not closely drawn, and quite often refer to sets of circumstances which are entirely different. Many believe that under exactly the same circumstances productivity in America and at home would not vary very considerably when measured in the units of work, per individual, or per square foot. It is a fact, however, that productivity in America measured either as that of the individual, or per square foot of floor area, is much higher to-day than it is in our own country, and this most important fact must be taken seriously into consideration by all production men, because in the last analysis it is they who have to produce the goods.

Many reasons have been advanced, and many excuses have been put forward, as to why we do not produce so much per head as the Americans. Quite a number of these excuses are the alibi of the inefficient. We are frequently told that our men will not produce as fast as the Americans, and while I feel that the American workman is more consistent in his application to his job, I do not think this by itself is the complete answer. In the opinion of several people whom I know, men who are qualified to pass opinion on this matter, high productivity in America is due very largely to superior leadership, coupled with a better understanding of the psychology of the workpeople than is common in our own country.

### High Wages versus Increased Output.

One opinion that is strongly held is that the Amerian success-

is due to high wages. Another opinion is that this success is due to the fact that American workmen work more consistently because they are given a greater stake—a bigger share in the proceeds of their industry. I put this to you, gentlemen, because there has been a tendency, and is still a tendency in this country, to regard wages paid to workpeople as having certain fixed values. The Americans pay high wages because they believe this is the only way to get high productivity. They are not at all sentimental over it, but do it in the name of good business. A study of economics may show that there may be some factor which will prevent us ever paying the same high wages that are paid in the United States, but there is no real reason, mental, physical, or otherwise, why, given the *same conditions* we cannot do the work in the same time.

### Who Holds the Key to the Problem of High Productivity?

My view is that we, as production engineers, do not hold the master key to the problem of why production is higher in America than in England, but I do think that we hold the key quite often in the matter of creating a correct atmosphere which shall be suitable to increased productivity. As production men we stand as a buffer between our directorate and our workpeople, and it is our duty to keep the peace between these two sections of the organisation. I am not suggesting here which of these two ends is at fault when productivity is low. It may even be the fault of the production engineer himself, but clearly it is in the interests of all that we do produce to the limit of our capacity.

Higher earnings are, I believe, absolutely essential if we are to achieve increased production, but high earnings themselves must of necessity be coupled with intensive effort. It does not at all follow that this intensive effort will mean harder work. For instance, high output may quite conceivably start with the production engineer who, noticing that a certain man has to walk round his machine to pull a lever, thinks out a scheme for preventing this waste. It may only be an electric push button, but the thought has been put into it. The movement which was waste has been cut out, and the production per unit has been increased. This is where the production engineer himself can add materially to the output of a plant.

### Wages.

Time is too short to deal with the question of wages, but the subject will yield good returns for any thought put into it. Payment by results is both logical and wise, and straight piecework with an extra bonus to the efficient seems to me to be the best way of achieving maximum output from our employees under any given set of conditions.

### Machines.

A question that frequently arises in discussions of why production is low is that our machinery has not been kept up-to-date. We have not the latest labour-saving appliances and, therefore, suffer by comparison with our American competitors. There is, I believe, no one in this room who has knowledge, who would say that industry in England has kept its machinery up-to-date. There are many of us who know that we can improve our output if we replace our old machines with the most modern of their type. I do not intend to pursue this side because the question of machines and their replacement is a matter that is solely concerned with individual works and their product. I only mention it in passing to introduce my opinion that the machining question is not the most vital one that we, as production engineers, have to consider.

Anyone who cares to analyse a set of costs made out on the basis of hours, analysed as between machine hours and all others, will find that machine hours are a relatively small proportion of the total. Apart from this, while I know that production engineers must study the latest type of producing machines that are made for them, they must never lose sight of the fact that minor modifications to their own plant will often produce results that are as good, or better, than they would obtain with a new machine.

Intelligent initiative on the part of the production force, coupled with willing co-operation on the part of the employees, can often achieve more than would result from the expenditure of capital on new machines. But the production engineer must keep himself posted in every machine tool that he may ever have to handle. He must know what savings can be made by the introduction of a new machine tool, and when he is convinced that it will pay to put such a tool into commission, he must then try and get the money necessary for its purchase. Just when to put in new machinery is, to-day, one of the hardest problems of works management, but getting the money is the most difficult part of the problem.

### Methods.

One of the primary considerations of the production engineer concerns those problems that deal with organisation. As our organisation grows in age, like the human body, it becomes stiff in its joints; often it becomes extremely inefficient. I do not mean by this that inefficiency is a sign of old age, neither do I mean to imply that age of necessity means inefficiency, but in all our organisations of any age, if a careful study is made, it will be found that there is a tremendous amount of lost motion. This lost motion means waste of human effort, and what we as production engineers have to do is to watch over every point where either material or effort is being wasted, more particularly over the waste of human effort.

This waste of human effort is the most important because if we waste a piece of material costing one shilling we know at once what our loss is, but if we waste, or allow to be wasted, one shilling's worth of labour, the re-actions from this, which are bound to be known, are tremendous in their repercussions. The wastage of a shilling's worth of labour may involve us in an expenditure of hundreds of pounds.

### Start at the Beginning.

In discussions about the speeding up of production to get quicker deliveries, or lower costs, almost invariably the point that is tackled is the shop. I suggest, gentlemen, that quite often this is the wrong end to begin at. Much greater savings, both in time and in the cutting of costs, can often be effected when this question is viewed from the other angle. It is suggested that the correct point at which to start, whether we are anxious to cheapen production, or to give more efficient delivery, is to start at the beginning, that is, start at the point where the order is received, and then proceeding from this point go through the organisation step by step up to the point where the work is despatched. When the question is tackled in this way you will find that instead of the order moving steadily, it will proceed in a series of hops. Quite often, too, owing to geographical considerations, the order itself will take a roundabout course through a number of hands, and each of these stops takes time and costs money.

### Waste Paper.

An examination along these lines will often show too that hosts of records are being kept that are of no value whatever. Each record takes time to compile, and when compiled takes up room and labour for filing. I maintain, therefore, that the starting point for all our considerations of increased production, or cheaper production, should be at the beginning, as I am confident that great savings can be made at the stage between the placing of the order and the works themselves.

Lost motion should be searched for in every phase of manufacture. No step in the line should be passed over without a critical examination as to the necessity of each step. No paper or routine should be allowed unless it can be shown that such routine is necessary, either for increasing production or recording the cost of same. If there is any suspicion at all that any paper routine is a step put in with a view to building up a separate section, and has no real bearing on either cheapening the work or hastening the delivery, then such paper work should be eliminated, and the people concerned transferred to useful work. It is not intended to convey the impression that records are not necessary, but merely to point out that many records that were useful in the past are not necessary

to-day, and to keep compiling them is waste of effort.

During the examination of this section of the organisation the production engineer should keep before him at all times the possibility of replacing manual work in the office, or in the recording of data that is necessary by machines. Greater savings could often be made here by the introduction of equipment costing £100 into the office than would be effected in the machine shop by the introduction of £10,000 worth of machinery.

#### Dead Wood and Weeds.

When I was going to America in 1928 I had the privilege of meeting an American business man—an Englishman born—who was much concerned about the condition of industry in the Old Country. He told me that the trouble with us was that we had in industry too much dead wood and too many weeds. He defined, for my benefit, dead wood and weeds as being capital and personnel that were not pulling their weight. This is worth thinking about. If you had a garden or shrubbery you would, I feel sure, take periodic steps to clear from your garden weeds, and from your shrubbery dead wood.

This question of weeds and dead wood in an organisation is one that requires particularly close attention, because industry to-day has too many weeds and too much dead wood. These weeds and this dead wood are feeding on soil that should be serving real growing plants. You will find if you make a periodic inspection of your organisation that there are many places where weeds and dead wood exist. It may be that your leverage is not sufficient to dislodge some of these weeds which have got anchored to something solid, but if you have the good of your department at heart you must call attention to the destroying effect of weeds on proper growth. I mention this because I think it has some bearing on why productivity is higher in America than over here. Inefficient machines are dead wood.

#### Monetary Interest versus Committees.

There are two other cases I would like to deal with under methods, because these also may have some bearing on the difference in productivity between the two countries mentioned. The two cases are possibly methods of management. They do, however, have a psychological effect on production, and I believe direct our thoughts towards points which we must investigate.

Recently I was looking over the report to stockholders issued by a large American company for the year ending December 31st, 1928. The number of employees in this concern at the beginning of the year was 40,000. At the end of the year it was 56,000. This is, as you will see, an average of 48,000. The payroll for this same company was \$88,500,000, which is an average per employee

of \$1,800, say £360 per year. These figures indicate, I think, the very high wages that are being paid in America, but that is not the point which I wish to place before you. There was during the year under review in this company, authorised deductions from payroll for thrift purposes a sum of \$8,700,000. You will see, therefore, that quite apart from any savings that the employees of this company may make outside, they saved as deductions from payroll 10 per cent. of the money they were earning, to be exact, 9.8 per cent. This is, you will admit, something that we could not possibly achieve in this country, but, and this, I think, is the keynote of the American success, and in any case it is the point to which I wish to direct your attention, during this same period out of this \$8,700,000 deducted from payroll \$5,648,000 represented subscriptions under the Employees Stock Purchasing Plan.

You will see, therefore, that five-eighths of the savings made by the employees of this company went back as working capital to enable work to be found for the employees by means of expansion of trade, expansion which is taking place all over the world. These schemes are definitely being used in America to promote good feeling, and to ensure full co-operation from their workpeople.

Now let us take methods that have been used in this country, and are still being used, ostensibly for the same purpose, namely, to get the co-operation and support of the employees.

During the war there stole into the industrial management what I regard as a thief in the night. We adopted in a number of cases, and are practising also in many cases to-day, what might be called management by committee. I want to put it to you that the committee is the standardised tool of the politician. Whenever an awkward position arises the politician appoints a committee to consider the matter. Should they report too soon the matter is referred back for further consideration. This can be carried on almost indefinitely, and situations that are really dangerous can be smoothed over. In the hands of the politician the committee is a most useful tool which can be used either for delaying action or for passing responsibility for action on to someone else.

Management, however, calls of necessity, for both decision and action, and when the committee is used as a tool of management it is the tool of the inefficient. If you cast your eyes round and find any really successful business, you will find that it is not run by a committee, but is dominated by some individual whose outstanding personality allows him to manage without the aid of a committee who can tell him nothing that will aid him in coming to a decision.

Committees in industrial management are of no use; they are wasteful of time and they are unfertile in their efforts. I do not want you to think from this that I personally have no consideration for the well-being of our human material. I would repeat what I have said previously, that there is no study which will yield better

returns than the study of the human material that we have in our charge. I do not believe, however, that you can study him through a committee. Conferences, however, can and often do achieve good results. As a matter of fact, the conference properly planned and efficiently carried out is one of the best ways of running a shop efficiently. The only substitute for the conference is a mass of paper and routine which, if it is fairly satisfactory at the beginning, often becomes sterile in a very short time. Paper and routine are poor substitutes for the energetic co-operation which can be brought about through the personal contact of leader and staff in conference.

Your problems are too varied for me even to make a catalogue of them in the time at my disposal. I do, however, want to emphasise the need for analytical thinking in dealing with production problems. There is one fact that is frequently overlooked, and that is that the method we used yesterday, which failed, may succeed when used to-morrow. Conversely, the methods that we are using to-day with success may be a failure to-morrow if tried under different conditions. The point about these remarks is that it is always dangerous to copy successful methods without analysing the reason why such methods were successful. It is, I believe, in this capacity to analyse the problems as and when they arise, that a man is either a successful engineer or otherwise, and this brings me to my third stage—the future.

### The Future.

Looking back on the achievements of the immediate past we get a wonderful—if dazzling—vision of the possibilities of the future. We have seen that the productive capacity of this island of ours, was increased enormously during the nineteenth century. We may be sure that its rate of increase in productive capacity during the remainder of the twentieth century will be such as to make the output of the nineteenth century look microscopic. What does this mean from the point of view of the production engineer? It means, as I see it, that while the problems of to-day are many, they will in the future be multiplied—and become more complicated. To tackle these problems with success will need intelligence of the highest order, coupled with a training in all that science can give us.

### The Science of Production.

I believe the production engineer of the future will be more scientific. You and I when given a problem in production, consider all the variables—that we can isolate—attach values to each according to our experience, then come to a decision as to the best way to proceed. Frequently I have thought that there should be better methods for solving such problems, methods that do not rely entirely on personal experience and judgment. I

have often wondered whether many of our problems could not be reduced to a formula capable of mathematical application. Some day I believe such a science will be evolved.

The beginning of any science has always been the tabulation and study of results that have been achieved, and I think that our lectures and the discussions that follow, must eventually result in production being put on to a more scientific basis. We, as production engineers, are particularly well served by our technical press, but what is wanted most of all is to get our younger members to interest themselves in those branches of scientific training which will help them to sort out the material at our disposal and reduce much of it to a formula.

Three main facts emerge from a survey of the data we have available from which to build up a science of production, first, the wealth of material at our disposal, secondly, the maturity of judgment and originality of the majority of those who have written or spoken on the subject of production, and lastly, the absence of any attempt to co-relate the data available in such a way that it shall form the basis of a science. Is it not possible that our Institution can take a hand in this matter and assist toward bringing it toward fruition?

In this connection I would like to quote from a book—"The Riddle of the Universe," written in 1899, in which the author, Ernst Haeckel, said : "In proportion as the various branches of the human tree of knowledge have developed during the century, and the methods of the different sciences have been perfected, the desire has grown to make them exact, that is, to make the study of phenomena as purely empirical as possible, and to formulate the resultant laws as clearly as the circumstances permit—if possible, mathematically." I believe that that quotation states our case fully.

How are we to develop ? Obviously through our younger members who will deal with the future. Quite clearly we, as an Institution, must take some hand in this question of scientific training. Educational authorities have on many occasions stated that while business men are prepared to criticise the training that is being given, they are not prepared with alternative proposals. You will have noted, no doubt, with pleasure, from the third issue of the Institution *Bulletin* that we as an Institution have ideas on what is wanted, and that contact has been made, and will be maintained, with educational authorities on this question of training.

The subject of education is a difficult one. To my mind education must do one, or both, of two things for us. It must assist in making life brighter by reason of a closer understanding of the things that matter, or it must provide us with some opportunity of being of real service to the community. Complete education fulfils both purposes.

### **Education.**

What is it? Is it something that we get by the aid of a teacher and which finishes as soon as we leave school or college? Or is it something that is going on the whole of our life and which is to-day known as experience? Obviously the technical training that a young man gets at school or college is merely the background. It is a tool for his use, and until he has learned to use it it is not much value to the community. Education to the young engineer is like the micrometer to the tool maker; the sextant to the sea captain; or the telescope to the astronomer; until each of these can use the tools of their trade they are not of much value.

I remember once having to start two tool makers. One came to me with a nice kit of tools, micrometers, verniers, etc., the other man was a down-and-out, one of the roving variety who never stopped anywhere long. Yet the first of these, although he had a whole set of tools, did not know how to use them. The rover, although he did not stop with me long, showed that with the tools available in the shop he could make anything from a jig to a compound die. The possession of tools is no criterion that a man is a tool maker any more than being in possession of a palette, set of brushes and a canvas, is an indication that the owner is an artist.

I do not wish to convey by any word that I may utter that education is not necessary. There never was a time when it was more vital than it is to-day, but it wants to be the right education and it must be absorbed in the correct atmosphere. It is, I think, fatal in dealing with educational matters to let young men ever get the idea into their head that the acquirement of an educational degree will instantly assure them of a position of authority in engineering. This is a feature to which educationalists must pay the strictest attention. Education by itself means nothing. It is only applied education that is valuable to the community, and to apply education to the needs of the community one must have experience, i.e., one must use it for the common good.

But whilst education, or technical education, is important, it is not the most important factor in the make-up of the Production Engineer. Recently I made an attempt to analyse what are the factors vital to success, and after mentally reviewing a number of successful Production Engineers, I came to certain conclusions. I believe you will find that any successful production engineer has ten outstanding characteristics, and in my opinion these—placed in order of relative importance—are:—(1) character; (2) a production mentality; (3) craftsmanship; (4) an analytic mind; (5) energy; (6) enthusiasm; (7) technical education; (8) initiative; (9) tact; (10) perseverance.

If you agree with me, then the specification for a successful production engineer would read somewhat as follows:—

A man of *character*, whose *mentality* is tuned to the need for

greater production, who has a fixed determination to make two blades of grass grow where only one had been growing previously. He must be a *craftsman* with an intimate knowledge of the processes he will use. The possession of an *analytic mind* will enable him to analyse the problems as they present themselves and decide which is the best method to adopt. Having made a decision he will carry the matter through with *energy*, and will attack any difficulty that may arise with *enthusiasm*. His *technical education* will be such that he can appreciate the work of the scientists, and he must possess *initiative* so as to make full use of scientific developments wherever possible, for the solution of his problems. In putting his methods into practice he will be as *tactful* as circumstances permit—having due regard to human inertia, but his main object must be achieved, and to ensure this *perseverance* is needed.

In looking over my list of outstanding characteristics you may think that I have forgotten that of leadership. This is an important characteristic, but any man possessed of the characteristics I have mentioned will have leadership almost automatically developed in him with practice.

#### Revolution or Evolution.

We have heard a good deal lately about the industrial revolution that is to take place, and many, no doubt, have tried to visualise what this will mean. A glance back will tell us that we as a nation have no use for revolutions. Any changes that take place will be evolutionary rather than revolutionary.

Rationalisation of Industry is being discussed everywhere, but no two authorities appear to agree as to just what it means. As I see it, it means applying to industrial management—in its larger field—those truths which the production engineer have been preaching for a long time, namely, standardisation ; concentration of effort ; elimination of waste, both human nad material, and improved distribution.

To achieve these ends those in charge of industry will adopt the same means as we in the works have used. We re-arrange our shops, re-group our machines, etc. Industrial management will re-group industries. Many of our rearrangements in the shop have been futile in the past ; so I believe will be many of the industrial concentrations that will be attempted. But the lines indicated by the present trend are in the right direction, and eventually trial and error will eliminate the unfit. Many who are thinking of these changes are curious as to where the leaders are to come from. Where are these super industrialists ?

In the past when leaders have been needed they have been found, and I have faith that as soon as those in charge of industry feel the need for leadership, then leaders will be found. At the moment our industrial leaders have not, in the main, realised that

they are in need of leadership. They are too much concerned about the handicaps that industry is suffering from, and too little concerned about the things that might be achieved with real leadership. When industry, as a whole, does realise the need for leadership, there will be a series of eruptions which will bring forward the dominating personalities that we, as an industrial nation, need so badly at the present time.

Professor John Tyndall, in an introduction to a book on "Experimental Researches in Electricity" by Michael Faraday, says : "When from an Alpine height the eye of the climber ranges over the mountains, he finds that for the most part they resolve themselves into distinct groups, each consisting of a dominant mass surrounded by peaks of lesser elevation. The power which lifted the mightier eminences, in nearly all cases lifted others to an almost equal height." May I suggest that when the industrial revolution has brought to the front a dominating personality, it will surround him—as in Tyndall's simile—with others almost as dominating. I believe that on this—what we may call, using a military term, a general staff—there will be a strong representation of production engineers, men who know production from beginning to end—men of character and perseverance, who line up with the specification I have already given you.

### The Production Engineer of the Future.

In thinking of the possibilities of the future I have often wondered if we, as an Institution, are not taking too narrow a view of production engineering. We are now in the "power" age, and many commodities that are at present made by hand will in the future be wholly machine made. Many industries which to-day scarcely use any machines will, in the near future, be dominated by the machine. If this does come to pass, then the management of such concerns will definitely get into the hands of men who, if not engineers, will have the mentality of the production engineer. I believe that in the future we shall find that many trained production engineers will leave what we regard now as engineering, and will go over to those other industries where the trained engineer has the best chance of success.

Let me illustrate what I mean by taking an extreme case, and I will take a commodity which we all use, namely, bread. At the present time this is made in almost every street in the city, made in a way that is wasteful, both of labour and material. Distribution too, is much too costly.

Let me attempt to give you a mental picture of how a production engineer would make bread. Project your mind into 1950 and visualise a huge bread factory making all the bread required for Birmingham. The factory would be built on the side of the railway so that the flour could be taken in underneath to a point where

hoists would convey it to the top of the building. Here it would go through dry mixers so that different grades of flour could be blended, and from this point proceed through dough mixers, passing in due course through electrically heated ovens. After leaving the ovens the loaves would be wrapped in greased paper and sealed by machines. The loaves would then be packed by machines into cartons for distribution, and these cartons would pass down chutes to a fleet of delivery vans, which would rapidly convey the bread to a number of distributing centres. To run such a plant we should want, not a baker, but an engineer, and the staff would be largely maintenance engineers. The control of such a bakery rightly belongs to the production engineer. This aspect is worth considerable thought.

### Conclusion.

May I conclude with a story concerning Faraday. During his lifetime he carried out something like eighteen thousand experiments, the results of which were entered into a long series of diaries. Faraday was an extremely modest man, as will be seen from the following. In one of his diaries, written when he was sixty years of age, at a time when his discoveries had built the foundations on which the electrical industry of to-day is erected, he wrote, "I must learn to observe!"

What a lesson for all of us. We must learn to observe ; learn to see the things that are actually around us ; learn to co-relate these things that we see ; learn also to apply them for the common good. If we do this we shall not only be better production engineers but better citizens.

Gentlemen, I have told you little that is new. I hope, however, that I have provided you with sufficient points to ensure a good discussion. In conclusion, I would once more like to thank you for the honour you have done me, and to assure you that anything I can do to further the interests of the Institution of Production Engineers will have my best efforts.

### Discussion.

MR. J. A. HANNAY (retiring President, Birmingham Section) : A month or two ago, in committee, we were reviewing the discussions that took place at our various meetings, and I was taken to task for being destructive and pulling lectures to pieces, so I am going to be a little bit careful. To-night I am not going to challenge anything that Mr. Grocock has said, though I may amplify some of his remarks. I would especially refer to our younger members. I am particularly anxious that we get young people to join us, because the whole future lies in the hands of the young people. Do and say what we like, when we get to the age of most of the members of the committee, we get into certain fixed routine ways

and it takes a good deal of change to move us out of them, but the young people have all the advantage of having nothing to throw off—they have only to put on. The salvation of the country depends upon production and upon costs. I think production engineers have lost sight of costs. I confess that I have not always given the question of costs the attention it should have. I would like to stress this, especially to the younger members. When you are dealing with production, watch your costs, and give all the help you can to anybody who can help you with your costs. The President referred to inspection. I would rather leave that alone. If we do our work right, if our jigs and tools and appliances are right, the inspector ought to fall behind—we ought gradually to cast him right off. It is only because there is something faulty in our methods that the inspector is necessary, and it is one of the expenses we must get rid of. I agree that the inspector is necessary in some processes, but let us eliminate him where we can. Mr. Grocock referred to the position in America and in this country. Well, I will only make one point on that. Last year something like five and a quarter million cars and commercial vehicles and trucks were produced in America. Not one quarter of a million was produced in this country. So there you see the proposition they have to face. If we could multiply our output by five or ten, we could offer some reductions. I was interested to hear Mr. Grocock refer to getting money for machines. Well, gentlemen, I would like him to say something about that. I have been in this game for well over thirty years, but I have never had enough money. It is a thing by which the production engineer is always handicapped. He could always do better if he could get more. About committees. I want to emphasise my agreement with Mr. Grocock. They are an abomination. Conferences here and there, just to make notes and let people know what is going on, are better. You cannot rule by committee. The only rule you will get is by an individual dominating and carrying through. If there is a man in charge, we have got to support him. When you are called upon to take control, take it and go right through and make everybody else serve under you. I think we can take a good picture from the Services, the police, etc., of the way people have to serve. Take an instance close at home—R. W. Morris. His whole success is because he has done the thing himself. As the concern has become bigger, he has deputed various duties to a board, but the whole success is because he has ruled and governed and directed. There is no doubt about it, he does govern, and that is the reason for his success. Another word to the younger ones. I had a talk with Sir Alfred Herbert some time ago. You know what a wonderful work Sir Alfred has done, and how he has built up such a vast organisation. He said he saw the possibilities and the need for better equipment forty years ago and, he says, to-day there is a greater need than ever.

We ought to take encouragement therefore from the possibilities before us. Craftsmanship. My one regret, I think, in mass production is the possibility of losing some of our craftsmanship, and I preach whenever I get an opportunity that anybody who has to design plant should keep in mind (unless it is absolutely automatic machinery) that the human element is going to direct the hands and limbs of the person who is to work that machine. When you are designing, make allowances for it so that the brain can be applied and developed. If we go along this line, our craftsmanship will not altogether vanish. I am afraid that in some of the American factories they have lost sight of it, and I doubt if they care whether there is any craftsmanship left. Unless we take care to develop the brains of our workers we are going to lose our craftsmanship. Last evening I had the pleasure of listening to a few speeches at the Employers' Federation dinner. The first toast was "British Industries," and so it went on, and it almost got to be a political meeting. Everybody seemed to think there was no hope for us unless we had protection or some other help, until the Principal of Birmingham University, speaking for the "Visitors" said he was confident that the engineering instinct and engineering skill in this country were going to put Great Britain further forward than she has ever been. He said he had travelled in America and on the Continent extensively, and had come back convinced that the world is going to be ruled and helped on by the engineer, and he was certain that the British engineer was going to take the lead. I cannot say anything of other countries, although they are doing many clever things, but I am quite convinced that the British engineer will come to the front.

MR. R. H. YOUNGASH : I should like to congratulate you, Mr. President, on having received this evening the highest honour that we can offer you at this Section, and also congratulate you on the successful way in which you have started to carry on our last President's work. The points that Mr. Grocock has put before us to-night must give food for reflection, and one that struck me as being outstanding was that relating to the characteristics necessary for success. Production engineers of the future will have a much more serious task than we have at present, owing to continual change of conditions, but they will have the advantage of a greater number of years of experience than we have, and the most successful then, as now, will be the man who can respond to the changes as they come along and not be discouraged by reverses and temporary failures, but combine engineering knowledge with the possibilities of economic production. I was talking the other day to a gentleman recently returned from Canada, who had been living at a small town some few hundred miles from Regina in the centre of Saskatchewan. He tells me that the bread there is actually made on the lines that Mr. Grocock has outlined to us to-night, so that Mr

Grocock's scheme is quite within the range of practical politics. He said, "Do you know that you are paying less for your bread than we are out there?" It struck me as being rather curious that we can import wheat into this country, make it into bread, and sell it at a lower price than they can out there, and after considering the subject I came to the conclusion that this is not true. It is not true because the rates of pay there are very much higher. If the wages there were double what they are here, then the cost of the loaf there would have to be one shilling to be equivalent to our price of sixpence. But it is not one shilling, but ninepence. It is a question of what we get for the wages we earn.

MR. I. H. WRIGHT: It gives me very great pleasure to congratulate Mr. Grocock on his accession to the office of President, and also on his address. About the need for this institution, I suggest that it is due to our having so many institutions which have grown largely out of the mediæval guilds, with their watertight compartments. If you are a mechanical engineer and interested in loco motives, you join the mechanicals. If you are interested in elevators and cranes, you join the civils. If you are interested in both, well, you have to join both. The American Society of Mechanical Engineers started out on better lines. They have one very large association, but it is divided into many sections. Its proceedings are published in many sections, and every subscribing member has a right to all the proceedings in full detail of two or three of these sections, and in special circumstances can get copies of papers read before any of the other sections. To do that in England would mean a complete reversal of all our traditions of engineering societies, but I believe very strongly that the American method is better, in that it not only provides each member of each section with information on the line of work that he is interested in, but it keeps him informed of the other sections of the institution as well. Mr. Grocock also mentioned education, and in that connection, experience. There has always been and always will be, as far as I can see, disagreement between the people who organise the work of the universities and the industrialists who have to employ the results of the universities' work, because, really, the industrialists do not want education, but instruction. They want a student to be delivered from the University with a mass of useful knowledge, which is not education, and in the same way, students go to school to learn, they do not go to be educated, and the tests are all "can you do this?"—"answer this?"—"can you solve that equation?" and so on, and that is instruction. It is not education. In the early years it should really be more education and less instruction. The instruction should come after the young person has definitely decided on some industrial career. That is the time when instruction becomes useful. Mr. Grocock also spoke about scientific data and the collection of it in such a form that it can be

reduced to definite rules. I have been in the mechanicals now for some thirty years, and my experience of them is that too large a proportion of their work is not scientific, in that it does not give definite facts and data which can be referred to later. One reason for my enthusiasm for the Institution of Production Engineers is that the production engineers are interested in facts. If this institution is to do what I want it to do, and what I am certain it should do, it is going to have to talk a great deal more about facts in its ordinary meetings and discussions than it has done in the past.

MR. T. S. RUMPH : It seems to me that industry is in a state of flux, and that the production engineer is trying to take a middle course. On the one hand, we are depending on pure science, and on the other we see the young people coming up with improved education. They all want to be bosses—they are not going to be mechanics. But we have got to have mechanics. We are in an age of change, when we might, say, have to change over from motor cars to aeroplanes, and unless we have got mechanics competent to make aeroplanes when the change comes, we shall be left behind. If we have so few mechanics, everything has got to be done in the toolroom. In America they have all the mechanics they need, as they take ours from us. This is a point where the man in the shop can help, and he should take a little personal interest in the work and try to get his mechanics to do so. It is absolutely necessary, or we shall not be able to make the rapid changes which will be necessary in the next few years. We want to try to take advantage of science and improved education on one hand, and to bring up mechanics on the other hand.

MR. R. HAZLETON (General Secretary) outlined the negotiations between the Institution and the Associations representing technical education with regard to the proposed scheme of examination for graduate membership of the institution and read the terms of the agreement that had been arrived at at a conference held in London in December.

MR. J. W. E. AIDNEY : I would like to raise a point which has not been stressed to-night, and that is that the production engineer should study more seriously than he has done in the past planning and efficiency of methods of production. There is quite a big field open for the production engineer there, and unless he takes it up in time, planning and efficiency engineers will do the production engineer out of the job. There is not time now to go into the question of advantages of planning methods, but I really think America's success is due not only to its large market and its sales force, which we all recognise as very good, or to its machines, but to the planning methods which they adopt in that country.

MR. S. A. BROWN : I have been very interested in the president's address and especially in his faith in the human element, and I

am glad it is unshaken. If the British workman is so much in advance of others, why does he not get better results? Speaking from the executive standpoint of the production department, I am going to say he has not much to be ashamed of, but rather is he very much disappointed at the support that he gets from other directions. If you change your production, you are often asked "Well, what is your production going to be on this?" and when you want to re-balance your plant to suit your production, you cannot get the machines. Why is it we cannot get the machines we ask for? I think our President answered that question when he explained that he has come across workmen who can do nothing with the aid of tools, while certain tramps can do practically anything without tools. I think directors look upon us as tool-less tramps, and we are expected to produce without the expenditure. That strikes me as being one of the chief dangers that we are up against in this country. I was struck by the remark of our President when, in putting down the characteristics of the production engineer, he placed enthusiasm first. Well, we know the value of enthusiasm, but we come across some men who, while full of enthusiasm, do the work first and think afterwards.

MR. J. W. BERRY : The President made rather a strong point—perhaps too strong—that education comes nearly at the bottom of the list of fundamentals. I should like to refer him to his first three fundamentals, character, mental attitude and craft. To my mind those three points are impossible of development without previous education. Education should be a foundation of those three fundamentals. We have got a wrong impression of education. I have every regard for the ordinary standards for the craft side of engineering, because, after all, engineering is a craft, but we are expecting too much of education if we are asking our schools and our technical colleges to teach a boy a trade. The proper place for a boy to learn his trade is in the factory, and no education received in a technical college or industrial college can take the place of the factory in teaching a boy his craft, but education on proper lines will give that boy the capacity to learn, the desire to learn, and the initiative to keep his eyes open. To my mind that is the fundamental of education. It is to open the boy's eyes and to make him better able to assimilate the teaching of the craft which can only be done in the works, and without education, the first three fundamentals of the production engineer are unattainable until manufacturers generally realise that point and approach the education authorities from that point of view.

MR. GROOCOCK in closing the discussion said that as the hour was late he could not reply to all the points raised. He would, however, like very briefly to refer to one or two of the more important ones. His entire sympathy went out to Mr. Hannay in his desire to eliminate inspection, but he thought that human nature,

being what it is, we shall always have to have some inspectors. He was of the opinion, however, that quite often there was more inspection than the product really needed. He agreed with Mr. Wright—who had spoken of the division into sections of the A.S.M.E.—and said that possibly if we had in this country a similar institution, then our own institution might never have been formed. Whether all the sub-divisions that exist to-day will survive is questionable, but the point was raised to make it quite clear that the production engineer must have an institute of his own as no other institute served his needs. Mr. Rumph spoke of the need for craftsmanship. This is very essential and one of the directions in which we can all do much better than we have been doing is by bringing up more boys in our tool rooms. Every job in the tool room can be sub-divided. For every three shillings wages expended in the tool room, two shillings go into work suitable for the training of boys—our future craftsmen. If we do not do this we shall simply go on stealing each others workmen as we are doing to-day, and thus be continually short of skilled men. Mr. Grocock then referred to planning and the efficiency engineer raised by Mr. Aidney. He said that planning was clearly one of the subjects that must be closely studied if the best results were desired. With regard to the efficiency engineer—so called—he had been found to be most inefficient. There was too much advertisement; too little efficiency. He rather liked the title of production engineer, and thought of him as an efficient man whose methods were efficient. In answer to Mr. Brown, he said that in his opinion the reason why the human element did not succeed so well as it deserved was in the failure of leadership. It is the policy of the directorate which will determine the measure of success that can be achieved in any particular business. It is the policy of the industrial leaders that is at fault to-day, and this failure in leadership is largely responsible for our relatively small production as compared with that of America. Replying to Mr. Berry, who had mentioned technical education, Mr. Grocock said—"I spoke of education in a broad sense. I placed technical education No. 7, and noted in the rough list, characteristics three to ten as being capable of training, these being craftsmanship, analytical mind, energy, enthusiasm, technical education, initiative, tact and perseverance. I think that character and production mentality can be strengthened by training, but I feel this, that an individual who is born without character will never have it, and the individual who is born with the wrong mental attitude will never be a production engineer. There are plenty of first class engineers who have good technical education, yet the production mentality is absent, and you can never get it into them. They would waste the whole of the week designing a nut when we do not want to design one nut for each job—we want to make a million. The production engineer is no more necessary than the

designing engineer ; each has a separate sphere and each, if successful, develops a mentality suitable to their work. One function of the production engineer is to give the designing engineer all the help he can so that the design can be as simple as possible to produce. The production engineer can assist the designing engineer very materially along these lines. Mr. Grocock concluded by saying that he did not expect technical schools to teach trades, neither did he expect that they would develop a curriculum that would turn out a successful production engineer without practice in the work. Technical education was a background to Engineering of any kind—just that and no more—a canvas on which to paint the picture of success.

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